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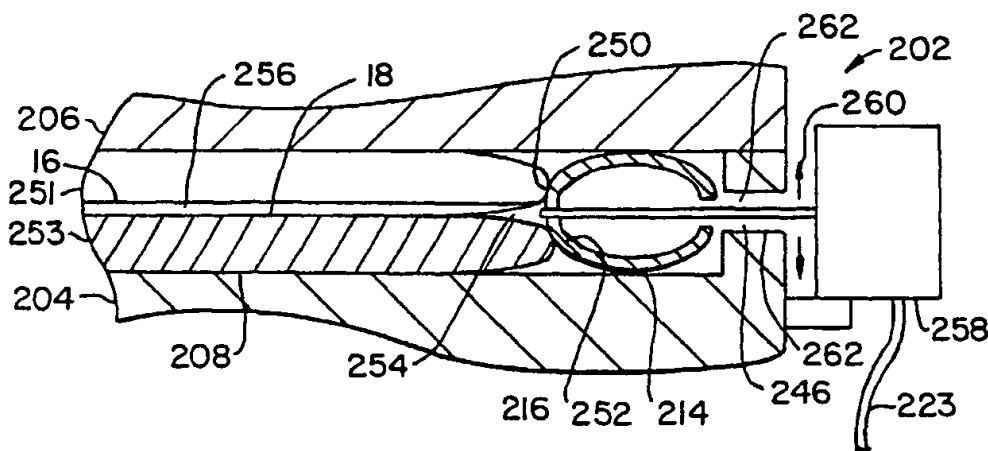
(43) International Publication Date
15 February 2001 (15.02.2001)

PCT

(10) International Publication Number
WO 01/10644 A1

- (51) International Patent Classification⁷: **B32B 35/00**
- (21) International Application Number: **PCT/US00/21006**
- (22) International Filing Date: **1 August 2000 (01.08.2000)**
- (25) Filing Language: **English**
- (26) Publication Language: **English**
- (30) Priority Data:
09/371,906 10 August 1999 (10.08.1999) US
09/371,436 10 August 1999 (10.08.1999) US
09/371,404 10 August 1999 (10.08.1999) US
09/370,958 10 August 1999 (10.08.1999) US
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- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:
— *With international search report.*
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: **METHOD AND APPARATUS FOR CLEAVING A SUBSTRATE**



(57) Abstract: A cleaving apparatus (600) impacts the perimeter of a substrate and then provides pressurized gas to the vicinity of the impact to cleave a substrate at a selected plane. The selected plane may be a weakened layer (18) in a donor wafer (12) in a thin film transfer process, for example. The substrate may be a composite substrate composed of flush-edged wafers (42, 46), or may be composed of one or more finished-edge wafers (12, 14). The combination of mechanical force and gas pressure separates the substrate into two halves at a selected interface, or along a selected plane.

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METHOD AND APPARATUS FOR CLEAVING A SUBSTRATE

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RELATED APPLICATIONS

This patent application is related to the following commonly assigned patent applications: METHOD AND APPARATUS FOR CLEAVING A SUBSTRATE, U.S. Application No. 09/371,906 (Attorney Docket No. 18419-004800); SUBSTRATE CLEAVING TOOL AND METHOD, U.S. Application No. 15 09/371,436 (Attorney Docket No. 018419-003300); METHOD AND APPARATUS FOR DETERMINING THE ENDPOINT OF A SUBSTRATE CLEAVING PROCESS, U.S. Application No. 09/371,404 (Attorney Docket No. 18419-008600); and NOZZLE FOR CLEAVING SUBSTRATES, U.S. Application No. 09/370,958 (Attorney Docket No. 018419-008700), all filed August 10, 1999, the disclosures of 20 which are hereby incorporated for all purposes.

BACKGROUND OF THE INVENTION

The present invention relates to substrates, such as may be used for integrated circuit fabrication, micro-machining applications, and similar substrates, 25 and more particularly to cleaving hybrid or composite substrates.

Semiconductor device fabrication technology continues to advance in the pursuit of smaller, faster devices. Integrated circuits devices have become more complex, and in many cases, bigger. New materials and methods are being developed to meet these and other performance requirements. For example, many 30 integrated circuits are fabricated on a silicon "wafer", which was sawn out of a generally round ingot, or boule, and polished on at least one side. Not long ago, silicon wafers typically had a diameter of about 2-4 inches. Then, six inch, and now eight-inch, wafers became commonplace, and the industry is moving toward silicon wafers with a diameter of twelve inches for some applications. The larger diameter

5 wafers can yield more chips per wafer, and improve throughput. Not surprisingly, the larger wafers are generally much more expensive than the smaller wafers.

Many integrated circuit devices are fabricated within a very narrow planar region close to the surface of the wafer. The remainder of the wafer provides mechanical support and may provide other functions, such as impurity gettering or a
10 backside electrical contact. Thus, the semiconductor material may only need to be of device (i.e. high) quality for a thin region near the surface of the wafer. Epitaxial growth processes have been developed to address this issue. Generally, a thin film of high-purity or other high-quality film of semiconductor material is grown on a substrate, which can be the same material, or a different material, than the grown
15 film. Unfortunately, epitaxial growth processes have not been easy to scale for use with the increased wafer diameters, and yields and throughput have suffered.

Wafer bonding is another process that uses a relatively thin film of semiconductor material. In some instances, a thin film of silicon, for example, is bonded to an insulating substrate, such as silicon oxide, to form a semiconductor-on-
20 insulator ("SOI") structure. Many techniques have been developed to bond one wafer to another, using adhesives, chemical activation, and the like. Some times a bulk wafer of silicon is bonded to an insulating substrate and then the silicon is lapped to the desired thickness, and other times a thin film of silicon is transferred to the insulating wafer.

25 Other wafer bonding methods have been developed for purposes other than to fabricate SOI substrates, such as transferring a thin film of high-quality semiconductor material onto a semiconductor or other substrate. Alternatively, it may be desirable to produce a thin film of material to form a layer in a micro-electrical-mechanical system ("MEMS") device. Accordingly, a technique and a
30 device for cleaving substrates is desirable for producing a thin film of material to be transferred and/or for separating bonded wafers from each other, and for other purposes.

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SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for cleaving substrates, including composite substrates.

In one embodiment, a composite substrate of two wafers bonded together has a flush edge or edges. In another embodiment, a composite substrate is formed from two wafers with finished edges bonded together. The edge of a tool, such as a blade, is tapped against the perimeter of the substrate in the vicinity of a weakened or stressed layer that forms a desired separation plane. It is believed the edge applies a wedging force against the two bonded wafers, creates a crack or scratch in the vicinity of a desired separation plane to lower the cleave initiation energy, and/or creates a small volume for a static source of gas to pry and force the substrate into two halves, cleaving along a selected plane. The mechanical tapping of the edge against the substrate may be done at the same process station as the gas application, or may be done independently of the gas.

A seal is formed around at least the portion of the perimeter notch that was tapped to define a plenum. A gas source is provided to the plenum to pressurize the plenum and separate the substrate into two halves at a selected plane. In a further embodiment, the wafers are held together prior to separation with a selected pressure to facilitate cleaving the wafers while reducing breakage. In a still further embodiment, the pressure applied to the substrate during the cleave process varies across the substrate in a selected fashion.

In another embodiment, a cleaving tool with an edge impinges on a composite substrate at or near a selected plane. The cleaving tool includes a gas port in the edge that provides a source of gas in the region of impingement. The combination of mechanical (solid-to-solid contact) force and gas pressure separate the composite substrate at a selected plane, with or without a perimeter notch formed by the edge finish of the substrates. In a further embodiment, the application of mechanical force triggers the pulse of gas from a source by actuating a valve for a selected period of time.

5 In yet another embodiment, a composite substrate of two wafers bonded together has a perimeter notch resulting from an edge-finishing process, typically performed by the wafer manufacturer, of one or both wafers. A seal is formed around at least a portion of the perimeter notch to define a plenum. A burst of gas is provided to the plenum to pressurize the plenum and cleave the substrate at a
10 selected plane. In a further embodiment, the wafers are held together prior to separation with a selected pressure to facilitate cleaving the wafers while reducing breakage. In a still further embodiment, the pressure applied to the substrate during the cleave process varies across the substrate in a selected fashion.

 These and other embodiments of the present invention, as well as some
15 of its advantages and features are described in more detail in conjunction with the text below and attached figures.

BRIEF DESCRIPTION OF THE DRAWINGS

 Figs. 1A to 1F are simplified cross sections of composite substrates
20 according to embodiments of the present invention;

 Fig. 2A is a simplified illustration of a wafer cleaving system;

 Fig. 2B is a simplified top view of a portion of the wafer cleaving system shown in Fig. 2A, further illustrating details of a gas port and an edge seal;

 Fig. 2C is a simplified cross section of a portion of a substrate cleaving
25 apparatus with a substrate disposed in a tool;

 Fig. 2D is a simplified cross section of an O-ring with a formed gas delivery tube;

 Fig. 2E is a simplified flow chart of a process according to the present invention;

30 Fig. 2F is a simplified diagram of a wafer cleaving system according to an alternative embodiment of the present invention;

 Fig. 3A is a simplified cross section of an O-ring and gas delivery tube with a tubing retainer;

5 Fig. 3B is a simplified cross section of an O-ring with a tubing retainer collet;

 Fig. 4 is a simplified cross section of a portion of a wafer-cleaving tool having another embodiment of an O-ring and base shell;

 Fig. 5 is a simplified representation of the relationship of various
10 elements of a cleave tool and a cleave front;

 Fig. 6A is a simplified sectioned view of an edged tool with an integrated gas port;

 Fig. 6B is a simplified representation of a wafer cleaving system using mechanical force and gas pressure;

15 Fig. 6C is a simplified flow chart of a process according to another embodiment of the present invention; and

 Fig. 7 is a simplified diagram of a cleaving method according to an embodiment of the present invention.

20 DESCRIPTION OF THE PREFERRED EMBODIMENT

 The present invention relates to a cleaving apparatus, method, and tools. Several situations may arise where it is desirable to cleave a substrate, such as to separate a thin film of material from a donor wafer, or to separate two bonded substrates.

25 A thin film separation method, known as a controlled-cleave process ("CCP"), is described in U.S. App. No. 09/026,027 by Henley and Cheung, filed February 19, 1998 (Attorney Docket No. 018419-000151), and which is incorporated by reference herein for all purposes. In the CCP process, ions and/or other particles are implanted into a wafer to form a cleave layer within the donor substrate. Energy
30 is then applied to the donor substrate to initiate and propagate a cleave front or fronts that separates a thin film of material from the donor substrate. Typically, a target, or handle, wafer is bonded to the donor wafer between the ion implantation step and the cleave step to form a composite wafer. The thin film remains attached to the handle

5 wafer after cleaving, and may be further processed to enhance the bonding between the thin film and the handle wafer.

Fig. 1A is a simplified cross section of a portion of a composite substrate 10 formed from a first wafer 12 bonded to a second wafer 14 at an interface 16. The first wafer has a weakened and/or stressed layer 18, which may have been
10 formed by implanting protons or other particles (e.g., hydrogen, deuterium, any combination of these) at a selected depth and concentration, using a plasma immersion ion implantation or beam line implantation or diffusion process, for example. The first wafer 12, as supplied from the manufacturer, has a finished edge 20 in the approximate shape of a truncated cone with rounded corners. The second
15 wafer 14, as supplied from the manufacturer, also has a finished edge 22, but in the approximate shape of a bullet nose. The shapes of the wafer edges are given as examples only, and illustrate that a perimeter groove 24 forms between wafers with finished edges. The perimeter groove typically extends essentially around the substrate (except, e.g., in the region of a wafer alignment "flat"), the depth of the
20 groove typically being greater than the wafer alignment error that occurs during bonding. Also, the design of the o-ring allows for mis-alignment.

Fig. 1B is a simplified cross section of a portion of a composite substrate 26 formed from a first wafer 28 having a finished edge 30 and a second wafer 32 having a flush edge 34. The edge of the second wafer has not been shaped
25 in a separate edge-finishing process; however, an artifact of a polishing process has left the corner 36 slightly rounded. The mating surfaces of the wafers that are bonded together to form a composite substrate are often polished to provide intimate surface contact in the bonding process. A perimeter groove 38 also forms between a wafer with a finished edge bonded to a wafer with a flush edge.

30 Fig. 1C is a simplified cross section of a portion of a composite substrate 40 formed from a first wafer 42 having a flush edge 44 and a second wafer 46, also having a flush edge 48. A relatively small notch 50 forms between the wafers as a result of the corner-rounding that occurred during the polishing process;

5 however, this notch may not extend around the perimeter of the composite substrate, depending on the alignment of the wafers to each other.

Other examples of composite substrates are illustrated by diagrams in Figs. 1D to 1F. These diagrams are merely examples, which should not unduly limit the scope of the claims herein. These substrates have been geometrically configured

10 in a manner to enhance the cleaving action and more particularly initiation of the cleaving action. Referring to Fig. 1D, substrate 100 includes handle wafer 101 and donor wafer 103, which includes stressed region 105. Separation of the donor substrate material will occur at the stressed region using, for example, a controlled cleaving process ("CCP"). In some embodiments, the wafers can include an

15 insulating layer 107 coating, which can be silicon dioxide or the like. Donor wafer includes a recessed region 109, which can be in a selected region of the periphery of the wafer or can also be surrounding the periphery of the wafer. The recessed region has a width 111 delta and extends to the edge of the wafer. The recessed region also has a depth, which is selected to enhance initiation using, for example, a pressurized

20 static fluid, e.g., liquid, gas. In some applications, the stressed region is exposed, i.e., free from silicon dioxide. Other applications can require a dynamic fluid. The recessed region has a gradual slope, which is not linear, but curved, and extends from the top surface of the donor wafer, extends over the stressed region, and extends to the edge of the donor wafer.

25 Referring to Fig. 1E, substrate 110 includes handle wafer 101 and donor wafer 113, which includes stressed region 115. Separation of the donor substrate material will occur at the stressed region using, for example, a controlled cleaving process. In some embodiments, the wafers can include an insulating layer coating (not shown), which can be silicon dioxide or the like. Donor wafer includes a

30 recessed region 118, which can be in a selected region of the periphery of the wafer or can also be surrounding the periphery of the wafer. The recessed region has a width 119 delta and does not extend to the edge of the wafer. The recessed region is off set from the edge, where a small gap 117 exists between the donor wafer and the handle wafer. The recessed region also has a depth, which is selected to enhance

5 initiation using, for example, a pressurized static fluid. Other applications can require a dynamic fluid. The recessed region has an annular shape or can also be a trench shape, which extends into the donor substrate to the stressed region or slightly above the stressed region at a point where the cleaving initiation can be implemented.

Referring to Fig. 1F, substrate 125 includes handle wafer 101 and
10 donor wafer 121, which includes stressed region 123. Separation of the donor substrate material will occur at the stressed region using, for example, a controlled cleaving process. In some embodiments, the wafers can include an insulating layer coating (not shown), which can be silicon dioxide or the like. Donor wafer includes a recessed region 122, which can be in a selected region of the periphery of the wafer
15 or can also be surrounding the periphery of the wafer. The recessed region has a width 131 delta and extends to the edge of the wafer. The recessed region also has a depth, which is selected to enhance initiation using, for example, a pressurized static fluid. Other applications can require a dynamic fluid. The recessed region has an annular shape or can also be a trench shape, which extends into the donor substrate to
20 the stressed region or slightly above the stressed region at a point where the cleaving initiation can be implemented. The recessed region also has a vertical side, which extends from the top of the wafer to the bottom 127 of the recessed region.

The above geometric features can be made using a variety of techniques. For example, they can be made using conventional masking and etching
25 processes. Additionally, they can be made using chemical polishing processes. Furthermore, they can also be made using mechanical processes. Still further, they can be made using any combination of these. Depending upon the application, a number of conventional techniques can be used to form the novel geometric features, which enhance initiation of the cleaving action.

30 Fig. 2A is a simplified representation of an apparatus 200 for separating a thin film(s) of material from composite substrates. A cleave tool 202 has a base shell 204 and a top shell 206 that can be separated (e.g. by lifting off or by a hinge mechanism) in order to load a composite substrate 208. The base shell is fabricated from a "hard" material, such as tooling plate (cast Al-Zn alloy) or other

5 The control line can be a simple switch, or can be controlled by a controller 230, such as a computer. The controller includes a processor 232 coupled to a computer-readable memory 234, as well as a display 236, and a user input 238, such as a keyboard. The memory 234 can include read-only memory, random-addressable memory, and/or magnetic or optical media such as a floppy disk, a hard
10 disk, or a compact disk. The memory stores a program 240 that configures the substrate cleave system to operate in a selected manner. It is understood that other controllers may be configured differently and have other appropriate block diagrams, or that the cleave system may be operated manually.

 A detector 242 may be included to determine whether the cleave
15 process has been completed. An indicator 244 receives a signal from the detector to indicate a change of condition of the composite substrate. The detector 242 can be an infrared source/sensor for example. When a cleave front propagates underneath the detector, the transmitted infrared light changes due to the separation of the wafer, resulting in an optical wedge that causes destructive interference of light at a specific
20 spacing created in the wafer. In an alternative embodiment, an infrared source in the base could illuminate a sensor in the cap. The transmissive path would be altered by the cleave front. Alternatively, the detector could be an ultrasonic transducer, or a heater/temperature sensor. A heater could provide a pulse of heat to the composite substrate, and the thermal decay could indicate whether the composite substrate is
25 intact, providing greater heatsinking and more rapid thermal decay, or whether the substrate has been cleaved. The indicator 242 can be coupled to the controller 230, or can provide a sensory signal for manual operation. Although the cleave indicator is shown in conjunction with a gas pressure cleave tool, a cleave indicator would be beneficial with other types of cleave tools, such as thermal or mechanical cleave
30 tools.

 Fig. 2B is a simplified top view representing the base 204 and the O-ring 214, which is shown as sectioned. The gas port 216 is the outlet of needle-like tubing 246, such as is used to make hypodermic needles. In a preferred embodiment, the tubing is made of type 316 stainless steel with an internal diameter of about 0.010

5 mm and 0.5 mm outside diameter. The tubing can be a product made by EFD Brand Part Number 5125CH-B. The gas port 216 is located about 10 mils out from the O-ring, i.e., the tubing protrudes out of the O-ring about 10 mils. A pin may be used to form the hole in the O-ring to push the tubing through. The tubing can also include a gas diffusion at its end in some applications.

10 Fig. 2C is a simplified cross view of a portion of the cleave tool 202 showing further details of the O-ring 214, composite substrate 208 and the gas port 216. The inside diameter of the O-ring is slightly larger than the diameter of the composite substrate, allowing the composite to be easily placed onto the base 204 of the cleave tool 202. When the top 206 is assembled to the base 204 of the cleave tool
15 202, the O-ring 214 is compressed into an oblong shape, moving the gas port 216 toward the center of the substrate and contacting the first edge 250 and the second edge 252 of the composite substrate 208 to seal the edge groove and form a plenum 254. The gas port 216 is situated within the plenum 254 to pressurize the plenum, thus creating forces to separate the first substrate 251 from the second substrate 253.
20 If the weakened layer 18 is weaker than the bonding interface 16, the composite substrate cleaves at the weakened layer and transfers a thin film 256 of the first substrate 251 to the second substrate 253.

A height adjustment mechanism 258 is provided to accurately align the gas port 216 with the edge groove/plenum. The height adjustment mechanism
25 moves, along with the tubing and gas port, relative to the top/base of the cleave tool, as represented by the arrows 260. Alignment accuracy within 0.2 mm or less is preferred, and is achieved with a manually adjusted lead screw. Other height adjustment methods may be used, such as a voice coil or stepper motor, and the height adjustment may be controlled by the controller (see Fig. 2A.). The gas line
30 223 to the height adjustment mechanism 258 is flexible to allow for the height adjustment. Similarly, the via 262 through the base 204 is larger than the tubing diameter, and may be an over-sized hole or a slot.

Fig. 2D is a simplified cross section showing a further refinement of the tubing and gas port or fluid port. The tubing 270 has a slight bend 272, of

5 between about 5-15 degrees that is about 3 mm back from the gas port 274, so that the bend occurs within the interior of the O-ring 214. This allows vertical adjustment of the gas port 274, represented by the arrows 276, by rotating the tubing 270, represented by the arrows 278. Rotational adjustment is used by itself or in conjunction with the height adjustment mechanism (see Fig. 2C) for fine, continuous
10 placement of the gas port. Rotating the tubing also allows an operator to confirm that the gas port is within the edge groove by providing tactile feedback as the gas port contacts one edge upon rotation in one direction, and then the other edge as rotation is reversed, if not used in an automated system.

Fig. 2E is a simplified flow chart representing a process 280 according
15 to the present invention. After placing a substrate on the base (step 282), the top is closed (step 284), which compresses the compliant pad against the substrate. As will be discussed in further detail below in relation to Fig. 5, the top is closed in a fashion to apply a greater force against the substrate in the regions further from the gas port. In a preferred embodiment of a substrate cleaving tool, closing the top also
20 compresses the perimeter O-ring to form a seal with at least a portion of the perimeter of the substrate.

Next, a pulse of gas is applied to a region on the perimeter of the substrate (step 286). If the substrate cleaving tool has a cleave indicator, the substrate is then checked for completion of the cleave (step 288). If the cleave is complete, the
25 process can stop (step 290). If the cleave is not complete, another pulse of gas may be applied. The subsequent pulse of gas may be of the same duration and pressure, or of a different duration and/or pressure than the initial burst of gas. It is noted that some substrates are easier to cleave than others, depending on the type of material and pre-cleave treatment (e.g. implant species, dosage, and energy), and that some
30 cleave processes may be consistent and reliable enough to be performed without a cleave indicator.

Fig. 2F is a simplified diagram of a wafer cleaving system 2000 according to an alternative embodiment of the present invention. This diagram is merely an example, which should not limit the scope of the claims herein. One of

5 ordinary skill in the art would recognize many other variations, alternatives, and modifications. Like reference numerals are used in this Fig. as the previous Figs. for easy referencing, but are not intended to be unduly limiting. Here, the cleaving system 2000 includes a variety of features such as base shell 204 and top shell 206 that can be separated from each other in order to load a composite substrate 208, 10 e.g., wafers. The base shell is fabricated from a hard and non-compliant material such as tooling plate, plastic, or other metals or combination of metals and plastics. The top shell has a hard, rigid cap 210, which houses an adjustable plate 2001. The adjustable plate is made of a flat material, which interfaces between adjustable members 2005 and compliant pad 212. Each of the adjustable members can adjust 15 the vertical or z-position of the adjustable plate. In a specific embodiment, there are more than one or preferably three or more members, which are spatially placed equal distance from each other on the top shell. Each of the adjustable members is adjusted in a manner to enhance the cleaving action of the composite substrate. The system also can have a plate 2003 and compliant pad 212 on the base shell. Here, the plate 20 on the base shell can be adjustable or fixed depending upon the application. The compliant pads support the faces of the substrate during a cleaving process while allowing such substrate to expand slightly to separate the substrate. The substrate separates a portion of the donor substrate material from the donor substrate.

An O-ring 214 forms a seal around the perimeter edges of the 25 composite substrate. The O-ring is hollow and operates at ambient (atmospheric) pressure to provide a compliance of 30 durometer, but could be sealed and pressurized to control the compliance and sealing force or could be solid. The system also has a fluid port 216, which provides compressed fluid into the chamber to initiate and maintain a controlled cleavage process.

30 The system also has clamping means 2007, which presses the base shell against the top shell. The O-ring is compressed between each of the shells to seal the outer periphery of the substrate against the O-ring. In a specific embodiment, the clamping means is a "Destaco" clamp or three of these clamps, which hold and maintain the base shell to the top shell. In a specific embodiment, the combination of

5 the adjustable members and the clamping means are adjusted to produce a desired pressure gradient on each of the faces of the substrate. The pressure gradient is adjusted by the adjustable members to produce a desired cleaving action. In a specific embodiment, the applied pressure on the substrate faces is greater near the fluid injection point and decreases further away from the fluid injection point. This
10 gradient may improve a cleaving action. Alternatively, the pressure across the faces of each substrate is constant and free from a gradient to improve cleaving action.

Fig. 3A is a simplified cross section of fine tubing 300 supported by a tubing retainer 302. The tubing retainer is co-axial with the fine tubing, and is a section of drilled metal rod, for example, glued to the tubing, but could be other
15 material, such as plastic. The tubing retainer 302 supports the fine tubing 300 to the interior surface 304 of the O-ring, thus increasing the stiffness of the tubing assembly and allowing for better height control of the gas port 306, as well as better durability, and the option of using finer and/or thinner-walled tubing.

Fig. 3B is a simplified cross section of fine tubing 310 supported by a
20 tubing retainer 312, which is further supported by a retainer collet 314. The retainer collet provides additional stiffness to the tubing assembly, and allows sub-assemblies of fine tubing and tubing retainers to be manufactured in anticipation of rapid exchanging of gas ports for maintenance or to configure the cleave system for different substrates. In lieu of a retainer collet, a tubing retainer with a stepped
25 diameter may be manufactured, either out of a single piece of rod, for example, or assembled from multiple pieces.

Although the above injector has been described in terms of tubing, it can also be may other means for supplying gas and/or fluid to the system. Here, the means can include, among others, almost any suitable member that directs fluid into
30 the system. The member can be shaped in a variety of configurations such as a rectangle, a semicircle, or other shape, which is suitable for directing the fluid into the system. The end of the means can be flared, pointed, or any other shape suitable for supplying the fluid. One of ordinary skill in the art would recognize many other variations, alternatives, and modifications.

5 Fig. 4 is a simplified cross section of a portion of a cleave tool showing alternative embodiments for the O-ring 414 and the bottom shell 402. The outer diameter of the O-ring is substantially greater than the thickness of the composite substrate. Additionally, the O-ring does not have a constant thickness, but rather has a thicker section 406 near the gas port. The thicker section of the O-ring
10 where the O-ring will contact the substrate to form an edge seal improves the contact force and stiffens the side of the plenum formed by the O-ring. An O-ring groove 410 is provided in the bottom shell, and a similar groove may be provided in the top shell (not shown), or the top shell may be flat.

 Fig. 5 is a simplified diagram representing how force is applied to the
15 top shell (not shown in this figure) to hold it against the bottom shell (not shown in this figure) and thus provide pressure to the composite substrate during the cleave process. A circle 502 as it would lie under the top shell represents the outline of a substrate. The position of the gas port is represented by the contact of a line with the circle 504. A cleave front is represented by a curved line 506, propagating in the
20 directions indicated by arrows 508. The shape of the cleave front is chosen solely for illustrative purposes, and does not necessarily represent the true shape of the cleave front, which depends on many factors, including the prior processing and type of composite substrate being cleaved. Force is applied at three locations, represented by the small circles 510, 512, 514. Force is generated by cam-over clamps mounted to
25 the base shell support structure. The top shell is placed on the base shell, and the clamps are set to force the top shell against the base shell and to compress the O-ring. The force the clamps apply may be adjusted by turning the clamp screw to extend the length of the clamp pad from the frame, as is well known. The nominal force of all clamps is set to provide a pressure on the substrate of about 5 to 50 psia. Then, the
30 clamp screws of the two clamps 510, 512 nearest the gas port 504 are extended an additional $\frac{1}{4}$ turn further than the clamp 514 furthest from the gas port. In some embodiments, stops may be disposed on the stage to prevent movement of the substrate, while the force is applied by to the substrate during initiation.

5 This provides a differential pressure across the substrate. A differential pressure is desirable because of the nature of the cleave initiation and propagation. In most materials of interest, the cleave is essentially a stressed fracture. The energy required to initiate such a fracture may be lowered by providing a local mechanical defect, such as a crack or scratch. Thus, once the cleave is
10 initiated in the low pressure region (near the gas port), higher pressure may be applied to the substrate to keep the cleaved halves from "jumping" and potentially breaking across the face of the half. A sensor, represented by a circle 518, is placed near the flat of the substrate to determine if the cleave has propagated through the substrate, as discussed above. Alternatively, a constant pressure may be applied,
15 depending on the type of material(s) the substrate is made of, the thickness of the cleaved halves, and the pressure and duration of the gas being applied, and other factors.

A pressure gradient may be important to prevent some composite substrates from flying apart and breaking when cleaved, while allowing the cleave to
20 form and propagate. It is believed the combination of the applied pressure gradient and the compliant pad in the top shell allow the efficient cleaving of composite substrates while avoiding breakage, especially of the donor substrate. It is recognized that other combinations of compliant pads and pressures may obtain similar results, and that different pressures and pressure gradients may be appropriate for different
25 materials or cleave conditions. Similarly, the force may be applied between the top shell and the base shell by a variety of mechanisms, such as pre-set springs, weights, gas or hydraulic cylinders, or even a compliant pad with a graded durometer, the durometer being less near the gas port, where the cleave is initiated.

Fig. 6A is a simplified sectioned view of a tool 600 that combines a
30 mechanical cleaving action with a pressure cleaving action. The tool has an edge 602 suitable for contacting the edge of a composite wafer. The composite wafer may have a perimeter groove, as shown in Figs. 1A and 1B, or may be composed of flush-edged wafers, as shown in Fig. 1C. The edge of the tool is lightly tapped against the edge of the composite substrate to help initiate a cleave. Gas is admitted to the cleave

5 region via a gas port 616 incorporated into the tool edge to help initiate and/or propagate the cleave formed by the mechanical action of the edge of the tool. In another embodiment, thick walled tubing with a small I.D., or rod with a small center through hole, is sharpened to a chisel edge. Alternatively, the process may be performed in two steps using a razor blade, for example, tapped against the edge of a
10 composite wafer before placing the composite wafer into a cleaving apparatus, as shown in Fig. 2A.

Fig. 6B is a simplified illustration of a substrate cleaving apparatus incorporating a tool similar to the tool shown in Fig. 6A. A composite substrate 40 formed from two substrates with flush edges, as shown in Fig. 1C, is placed in the
15 cleaving tool. An edged tool 601 extends through the O-ring 614 to contact the edge 604 of the composite wafer. The edged tool is tapped against the composite substrate by letting a weight 606 of a selected mass supported by an arm 608 of selected length fall a selected height, h , to contact the edge tool so that the edge of the tool taps the edge of the composite wafer with a selected force and momentum. Other mechanisms
20 can be used to create the desired force, such as a spring-loaded trigger mechanism or a pneumatic cylinder. A force sensor 610, such as a strain gauge or electrical switch, detects when the weight strikes the edged tool and triggers a pre-set pulse of gas from the gas source 220, controlled by the valve 222, which is coupled to the pressure sensor. Additional control structure is not shown for purposes of clarity, as such
25 structure is well known in the art.

Fig. 6C is a simplified flow chart of a cleave process 620 according to another embodiment of the present invention. A substrate is first tapped with an edged tool as shown in Figs. 6A and 6B. It is believed that this can have many effects that promote cleaving, including providing a wedging force between the
30 eventual cleaved halves of the substrate, initiating a scratch or crack to lower the energy required to initiate a cleave, and to form a small volume for the gas to enter and separate the substrate by gas pressure. After tapping the perimeter of the substrate with the edged tool, gas pressure is applied to the tapped region, as described above. The tapping and gas pressure may be performed essentially

5 concurrently, sequentially in the same substrate cleaving tool, or at different locations and times.

Fig. 7 is a simplified diagram of a cleave initiation process 700 according to an embodiment of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims herein. One of
10 ordinary skill in the art would recognize many other variations, alternatives, and modifications. The initiation process shows mechanical member 707, which can be in at least one or more process stages. Mechanical member includes at least an edge 706, which can begin separation of the stressed region 703 on the donor substrate. As shown, the donor substrate is bonded to the handle substrate. The member can be
15 at a first location 711 (shown as dotted lines), which is generally outside the periphery of the substrate. The member moves toward the substrate and begins a prying action between the donor and handle substrates, as shown by the structure in reference numeral 709. The prying action causes a separation of the donor substrate or crack 705 from the surface of the donor substrate toward the stressed layer. Once
20 the separation has been initiated, fluid is supplied through the orifice 713, which pries the material above the stressed region off of the donor substrate according to the methods described herein. Preferably, the member has a wedge shape, which begins with a pointed region (e.g., sharp, blunt) and extends toward a wider region, where the surfaces of the member pry apart or crack the donor substrate. A top view
25 diagram of the mechanical member illustrates an annular surface 706, which mates with the profile 711 of the substrate. The annular surface is intended to evenly distribute the mechanical member across a periphery of the substrate. Of course, the profile can also be negatively sloped, square, or positively sloped depending upon the application.

30 While the above is a complete description of specific embodiments of the present invention, various modifications, variations, and alternatives may be employed. For example, although the substrates discussed have been generally round, substrates of other shapes, such as a rectangular shape, could be used. Specifically, a silicon-on-silicon wafer may be used instead of a silicon-on-insulator

- 5 wafer, or a silicon carbide, gallium-arsenide, or silicon-germanium wafer may be surface finished. Additionally, the cleaved surface of the donor wafer could be prepared for another thin-film transfer by the above methods. Other variations will be apparent to persons of skill in the art. These equivalents and alternatives are intended to be included within the scope of the present invention. Therefore, the
- 10 scope of this invention should not be limited to the embodiments described, and should instead be defined by the following claims.

WHAT IS CLAIMED IS:

1 1. A method for cleaving a substrate, the method comprising:
2 tapping a perimeter edge of the substrate with edge of a tool to initiate a
3 mechanical separation in the substrate; and
4 applying gas pressure to the perimeter edge of the substrate to maintain
5 the separation of the substrate.

1 2. The method of claim 1 wherein a gas port is disposed in the edge
2 of the tool and is coupled to a gas source to allow the tapping step and the applying
3 step to be performed with the tool.

1 3. The method of claim 1 further comprising a step, between the
2 tapping step and the applying step, of forming a seal about a gas port with at least a
3 portion of the perimeter edge of the substrate.

1 4. The method of claim 2 wherein the tool further comprises a force
2 sensor to detect the occurrence of the tapping step, the method further comprising
3 steps, after the tapping step, of providing an output signal from the force sensor and
4 triggering the applying step according to the output signal.

1 5. The method of claim 4 further comprising a step, between the
2 providing an output signal step and the triggering step, of waiting a selected period of
3 time.

1 6. The method of claim 2 wherein the gas port has a diameter of
2 about 0.6mm and wherein the applying step comprises applying a pulse of gas at a
3 source pressure of about 300 psig for a period of about 22 msec.

1 7. The method of claim 1 wherein the applying step comprises
2 applying a first pulse of gas, and further comprising a step, after the applying step, of
3 applying a second pulse of gas.

1 8. The method of claim 1 wherein the tool is a razor blade.

1 9. An apparatus for cleaving a substrate, the apparatus comprising:
2 a base configured to support a substrate;
3 a top, movably coupled to the base, the substrate being disposed
4 between the base and the top;
5 an edge seal capable of forming a fluid seal around at least a portion of a
6 perimeter of the substrate when the substrate is in the apparatus; and
7 a tool movably disposed in the apparatus, the tool having edge and a gas
8 port disposed in the edge, at least a portion of the edge and the gas port extending
9 through the edge seal capable of contacting the perimeter of the substrate, the edge
10 being configured to impact the perimeter edge of the substrate when a mechanical force
11 is applied to the tool to move the tool toward the substrate and the gas port being
12 configurable to provide gas pressure to the perimeter of the substrate in a vicinity of
13 impact.

1 10. The apparatus of claim 9 further comprising:
2 a sensor coupled to the tool, the sensor capable of detecting a force
3 applied to the tool, the sensor providing an output; and
4 a valve disposed between and coupled to the gas port and a gas source,
5 the valve being coupled to the sensor, the valve actuating in a selected fashion
6 according to the output of the sensor.

1 11. The apparatus of claim 10 wherein the sensor is a strain gauge.

1 12. The apparatus of claim 10 wherein the sensor is an electrical
2 switch.

1 13. The apparatus of claim 10 further comprising a tapping device,
2 the tapping device configured to provide a force impulse to the tool to cause the tool to
3 impact the substrate and to cause the sensor to provide the output.

1 14. The apparatus of claim 13 wherein the tapping device is a weight
2 of selected mass supported by an arm of selected length.

1 15. The apparatus of claim 13 wherein the tapping device is a
2 spring-loaded trigger.

3 16. An apparatus for cleaving a substrate, the apparatus comprising:
4 a base configured to support a substrate;
5 a top, movably coupled to the base, the substrate being disposed
6 between the base and the top;
7 an edge seal capable of forming a gas seal around at least a portion of a
8 perimeter of the substrate when the substrate is in the apparatus and the top is coupled
9 to the base;
10 a tool movably disposed in the apparatus, the tool having a sharpened
11 edge and a gas port disposed in the sharpened edge, at least a portion of the sharpened
12 edge and the gas port extending through the edge seal capable of contacting the
13 perimeter of the substrate;
14 a switch disposed on the tool to detect when a force impulse is applied
15 to the tool, the switch providing a switch output;
16 a controllable valve coupled to the gas port and configured to accept
17 pressurized gas from a gas source, the controllable valve coupled to the switch and
18 being controlled in a selected fashion according to the switch output; and
19 a spring-loaded trigger configured to provide the force impulse to the
20 tool at a selected time.

21 17. A method of cleaving a substrate, the method comprising:
22 placing the substrate on a first portion of a substrate cleaving shell;
23 placing a second portion of the substrate cleaving shell on the substrate,
24 the substrate having a first perimeter edge and a second perimeter edge, to compress
25 and seal a compliant member against the first perimeter edge and the second perimeter
26 edge of the substrate to form a plenum; and
27 applying pressurized fluid through a gas port into the plenum.

1 18. The method of claim 17 wherein the pressurized gas is applied
2 as a burst of pressurized gas.

- 1 19. The method of claim 18 wherein the pressurized gas is at a
2 pressure of about 300 to 600 psig, and the burst has a duration of about 22 msec.
- 1 20. The method of claim 17 wherein the compliant member is an O-
2 ring.
- 1 21. The method of claim 20 wherein the O-ring is hollow.
- 1 22. The method of claim 21 further comprising a step, after the step
2 of placing the substrate onto the first portion of the cleaving shell, of pressurizing the
3 O-ring.
- 1 23. The method of claim 17 wherein the substrate cleaving shell
2 includes a compliant pad between the substrate and either the first portion or the second
3 portion of the substrate cleaving shell, the step of placing the second portion of the
4 substrate cleaving shell on the substrate further operating to compress the compliant
5 pad against the substrate at a selected pressure.
- 1 24. The method of claim 23 wherein the compliant pad is a rubber
2 pad with about 30 durometer.
- 1 25. The method of claim 17 further comprising a step, prior to the
2 step of applying pressurized gas, of impacting at least the first perimeter edge or
3 second perimeter edge with an edge of a tool.
- 1 26. A method of cleaving a substrate, the method comprising:
2 placing the substrate on a base;
3 compressing a top against the substrate through a compliant pad
4 having a durometer of about 30 to apply a selected compressive pressure
5 gradient to the substrate;
6 compressing and sealing an O-ring against a first perimeter edge of the
7 substrate and a second perimeter edge of the substrate to form a plenum;
8 providing a gas port to the plenum; and

9 pressurizing the plenum with a burst of gas via the gas port to cleave the
10 substrate, wherein the pressure gradient increases from an initial pressure near the gas
11 port.

1 27. An apparatus for cleaving a substrate, the apparatus comprising:
2 a base configured to accept and support a substrate;
3 a top movably coupled to the base, the substrate being disposed between
4 the base and the top;
5 a compliant pad proximate to the substrate such that when the top is
6 coupled to the base, a selected amount of pressure is applied to the substrate through
7 the compliant pad;
8 an edge seal capable of forming a gas seal around a perimeter of the
9 substrate when the top is coupled to the base to form a plenum; and
10 a gas port coupled to the plenum and capable of providing gas to the
11 plenum to pressurize the plenum and cleave the substrate.

1 28. The apparatus of claim 27 wherein the compliant pad comprises
2 rubber with a durometer of about 30.

1 29. The apparatus of claim 27 wherein the pressure applied to the
2 substrate is applied as a pressure gradient increasing from an initial pressure near the
3 gas port.

1 30. The apparatus of claim 27 further comprising:
2 a gas source capable of providing gas at a gas pressure of about 300
3 psig; and
4 a valve disposed between the gas source and the gas port, the valve
5 capable of modulating the flow of gas from the gas source to the gas port to create a
6 burst of gas at the gas port.

1 31. An apparatus for cleaving a substrate, the apparatus comprising:
2 a base configured to accept and support a substrate having an edge
3 groove;

4 a top movably coupled to the base, the substrate being disposed between
5 the base and the top;

6 a rubber pad incorporated into the top, the rubber pad applying a
7 selected amount of pressure, as a pressure gradient, to the substrate when the base is
8 coupled to the top;

9 an O-ring essentially surrounding the substrate and forming a gas seal
10 with at least a portion of a perimeter of the substrate to form a plenum between the
11 edge groove and the O-ring;

12 a tube extending through the O-ring, an end of the tube forming a gas
13 port in the plenum, the tube being coupled to a valve capable of modulating gas at a
14 pressure of at least about 300 psig from a gas supply through the tube into the plenum.

15 32. A method of separating a substrate along a major plane into two
16 halves, the method comprising:

17 applying energy to the substrate to separate the substrate into two
18 halves;

19 sending a test signal through the major plane of the substrate; and

20 detecting the test signal at a selected location, the location being
21 selected according to a least likelihood of separation, to determine whether the
22 substrate has completely separated into two halves.

1 33. The method of claim 32 wherein the energy is thermal energy.

1 34. The method of claim 32 wherein the test signal is a beam of
2 infrared light.

1 35. The method of claim 32 wherein the test signal is an ultrasonic
2 pulse.

1 36. The method of claim 32 wherein the energy is applied at a region
2 on a perimeter of the substrate and the location of detection lies on a chord of the
3 substrate essentially opposite the point where the energy is applied.

1 37. A method of cleaving a substrate into two halves, the method
2 comprising:
3 placing the substrate on a first portion of a substrate cleaving shell;
4 placing a second portion of the substrate cleaving shell on the substrate,
5 the substrate having a perimeter edge, to compress a compliant member against the
6 perimeter edge;
7 applying a pulse of pressurized gas through a gas port against the an
8 initial region on the perimeter edge of the substrate;
9 sending a beam of infrared light through a major surface of the
10 substrate; and
11 detecting the beam of infrared light at a point on the substrate to
12 determine whether the substrate has been cleaved beneath the point.

1 38. The method of claim 37 further comprising, after the detecting
2 step, the step of:

3 applying a second burst of gas to the initial region of the perimeter.

1 39. A method of cleaving a substrate, the method comprising:
2 placing the substrate on a base;
3 compressing a top against the substrate through a compliant pad having
4 a durometer of about 30 to apply a selected compressive pressure gradient to the
5 substrate;
6 compressing an O-ring against a first perimeter edge of the substrate and
7 a second perimeter edge of the substrate to form a plenum;
8 providing a gas port to the plenum;
9 pressurizing the plenum with a burst of gas via the gas port, wherein the
10 pressure gradient increases from an initial pressure near the gas port;
11 sending an infrared signal through a major surface of the substrate; and
12 detecting the infrared signal to determine if the substrate has been
13 cleaved into two halves.

1 40. An apparatus for cleaving a substrate, the apparatus comprising:
2 a base configured to accept and support a substrate;
3 a top movably coupled to the base, the substrate being disposed between
4 the base and the top;
5 a compliant pad proximate to the substrate such that when the top is
6 coupled to the base, a selected amount of pressure is applied to the substrate through
7 the compliant pad;
8 an edge seal capable of forming a gas seal around at least a portion of a
9 perimeter of the substrate when the top is coupled to the base to form a plenum;
10 a gas port coupled to the plenum and capable of providing gas to the
11 plenum to pressurize the plenum and cleave the substrate;
12 a source of a test signal disposed to send the test signal through a major
13 plane of the substrate; and
14 a detector disposed to receive the test signal to indicate the cleaving of
15 the substrate proximate to the detector.

1 41. The apparatus of claim 40 wherein the source and the detector
2 are a single component.

1 42. The apparatus of claim 40 wherein the source is an infrared
2 source.

1 43. The apparatus of claim 40 wherein the source is an ultrasonic
2 source.

1 44. The apparatus of claim 40 further comprising:
2 a controller coupled to the detector and configured to receive a cleave
3 signal from the detector; and
4 a valve disposed between and coupled to the gas port and a gas source,
5 and the valve being coupled to the controller, the controller actuating the valve to
6 provide a burst of gas if the cleave signal is not received from the detector.

1 45. An apparatus for separating a substrate into two planar halves,
2 the apparatus comprising:
3 an energy source configured to provide a selected amount of energy to
4 the substrate to separate the substrate along a selected plane;
5 a source providing a test signal, the test signal impinging upon the
6 selected plane; and
7 a detector configured to receive the test signal, the test signal being
8 altered by the separation of the substrate into two halves.

9 46. A tool for cleaving a substrate, the tool comprising:
10 a body portion having an end;
11 a chisel edge portion formed on the end of the body portion; and
12 a gas chamber wall defining a gas via through the tool, the via
13 terminating in a gas port disposed along the chisel edge portion of the tool.

1 47. The tool of claim 46 wherein the gas port is disposed at
2 essentially a center of the chisel edge portion.

1 48. The tool of claim 46 wherein the body portion is essentially
2 cylindrical and the gas chamber wall defines the via essentially along the center axis
3 of the body portion.

1 49. The tool of claim 46 wherein the gas port has a diameter of about
2 0.51 mm.

1 50. The tool of claim 46 wherein the tool has a face, the face being
2 opposite the end, and further comprising a force sensor disposed on the face, the force
3 sensor providing an output when struck.

1 51. The tool of claim 46 wherein the body portion is stepped to
2 create a first thickness and a second thickness, the first thickness being proximate to
3 the chisel edge portion and being less than the second thickness.

- 1 52. The tool of claim 46 wherein the body portion has an essentially
- 2 rectangular cross section normal to the via.

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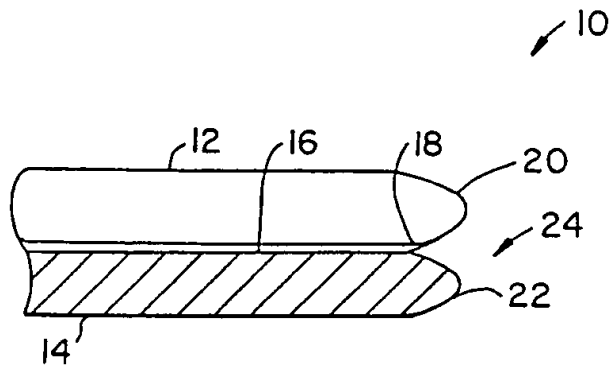


FIG. 1A.

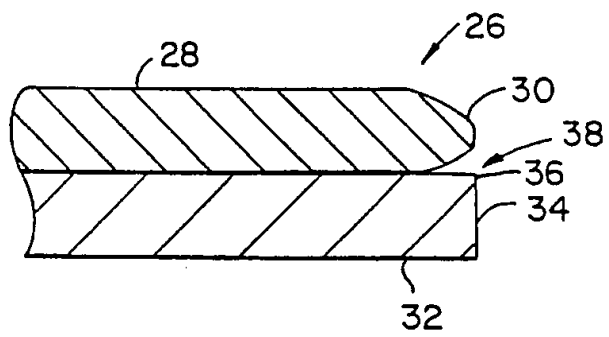


FIG. 1B.

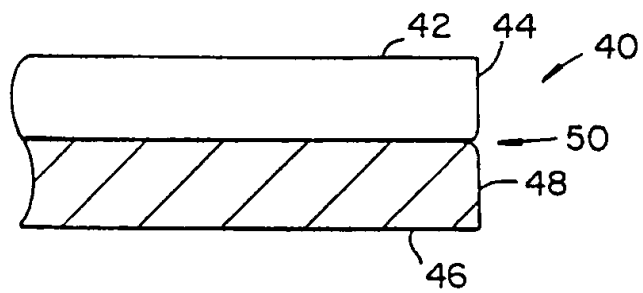


FIG. 1C.

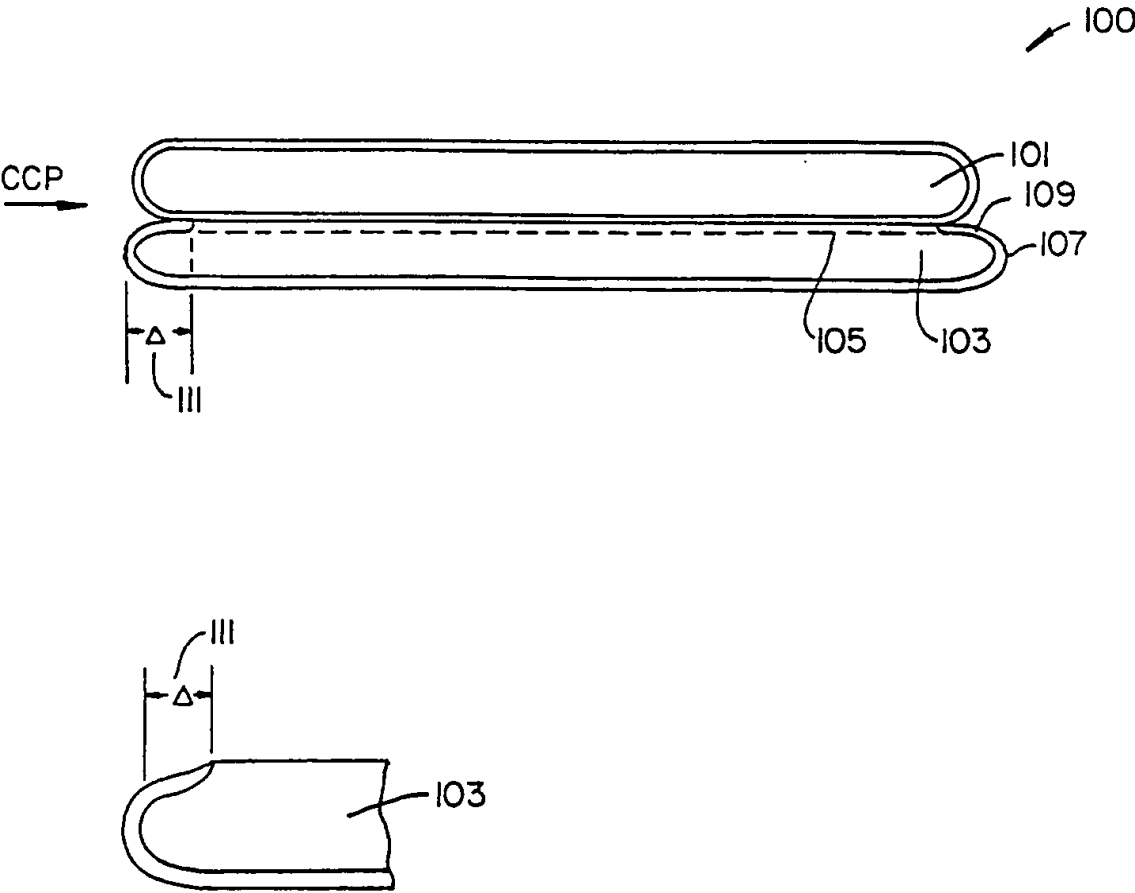
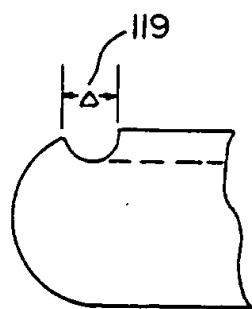
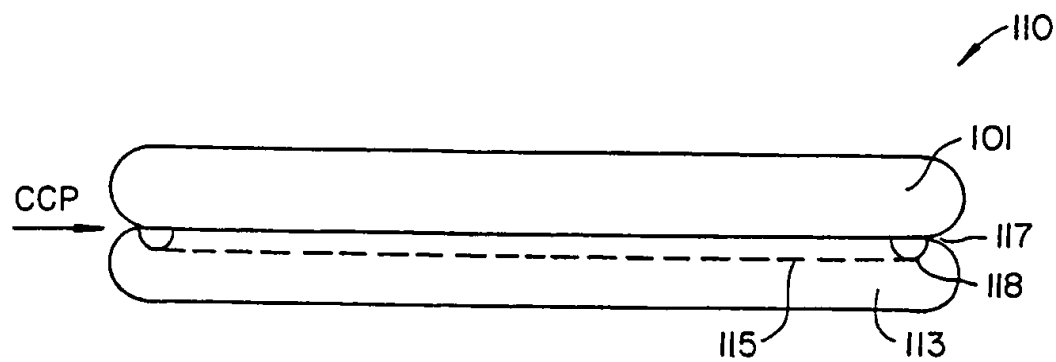
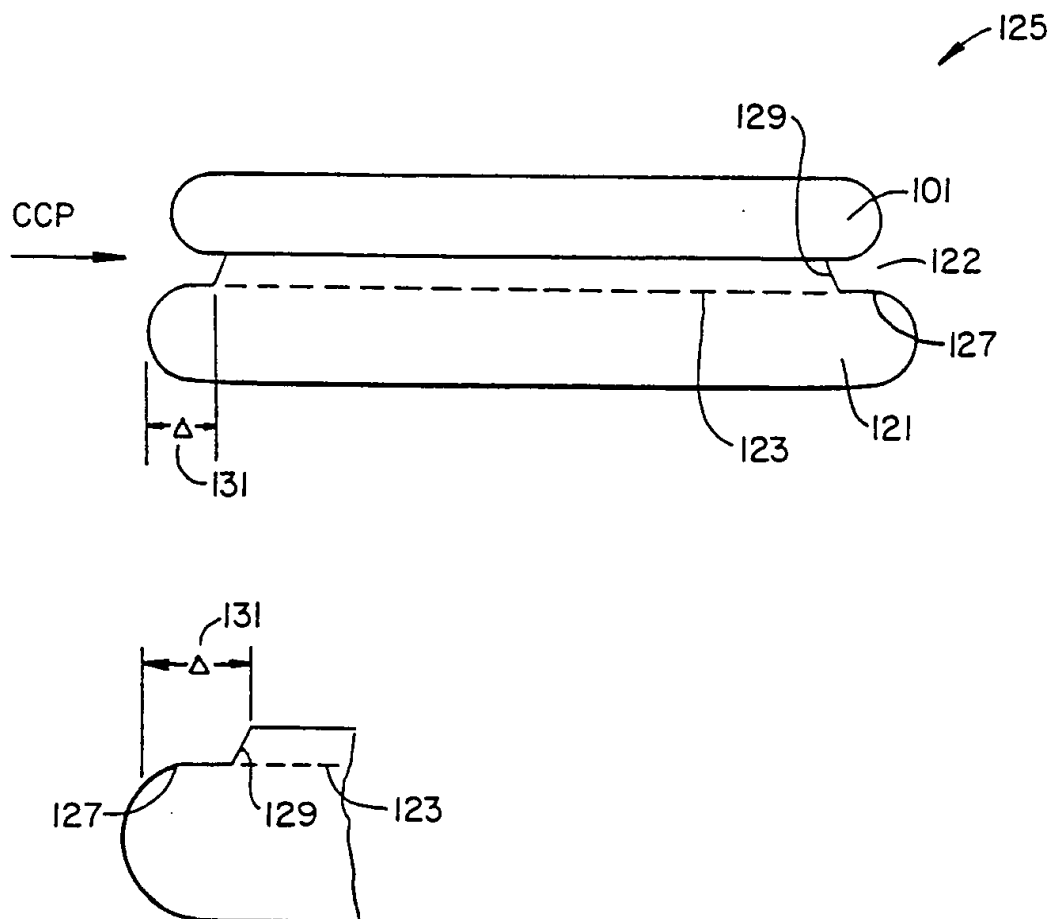
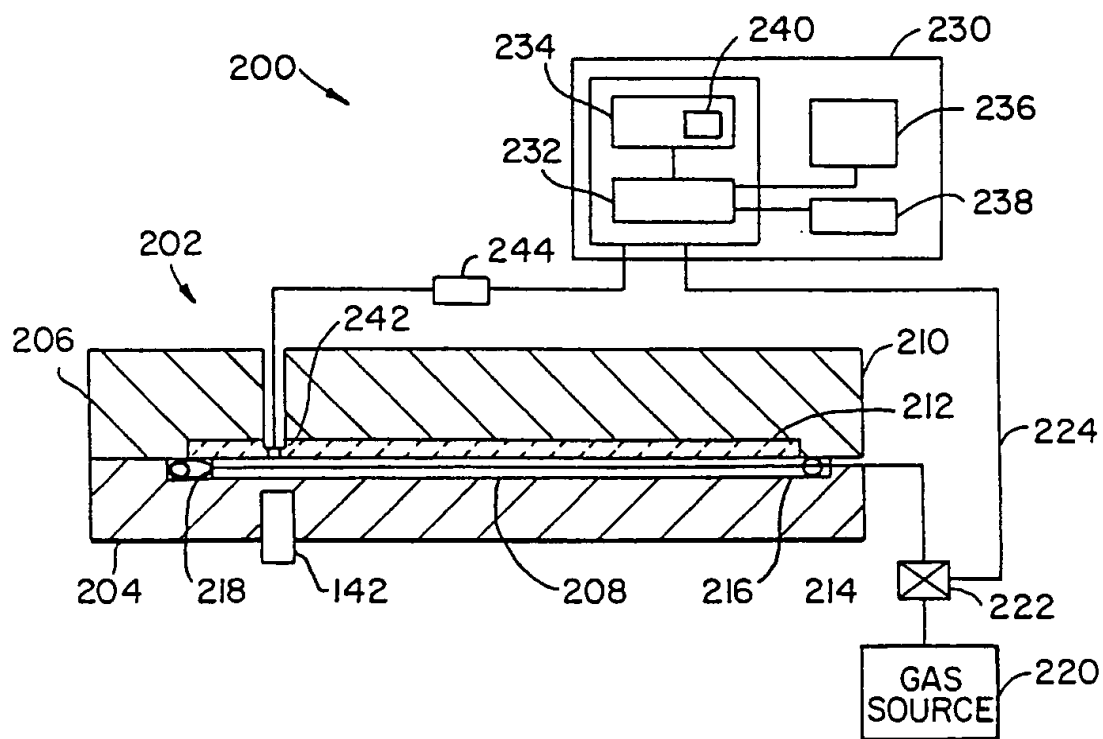


FIG. 1D.

*FIG. 1E.*

*FIG. 1F.*

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*FIG. 2A.*

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/21006

A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

156/239, 344, 529, 584; 73/598, 600; 83/177; 81/3.48; 29/426.4, 426.5; 438/455, 458

B. FIELDS SEARCHED

Minimum documentation searched

Classification System: U.S.

156/239, 344, 529, 584; 73/597, 598, 599, 600; 83/177; 81/3.47, 3.48, 3.55, 3.7; 29/426.4, 426.5, 762; 438/455, 458;
30/167, 167.1

6/13

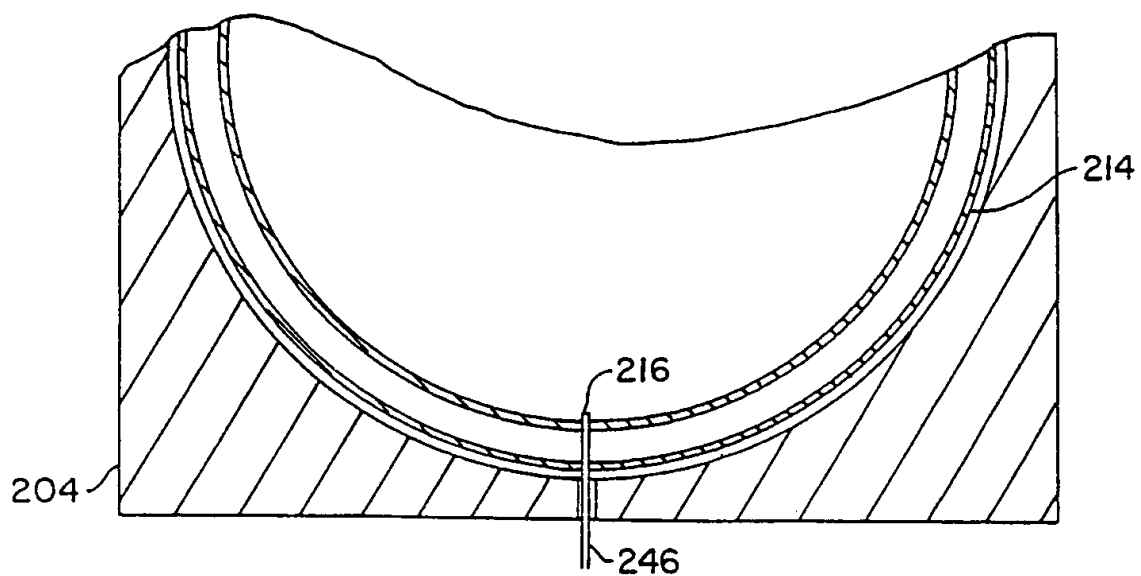


FIG. 2B.

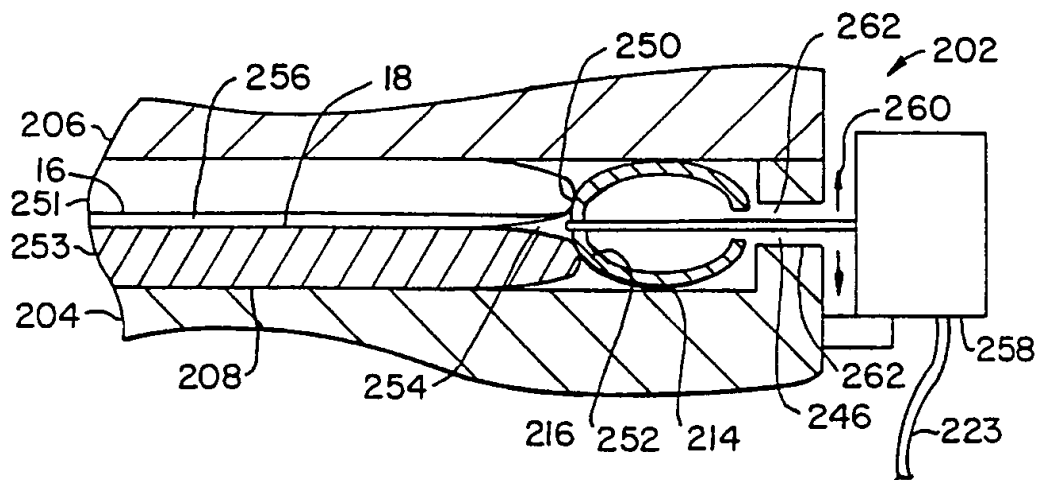


FIG. 2C.

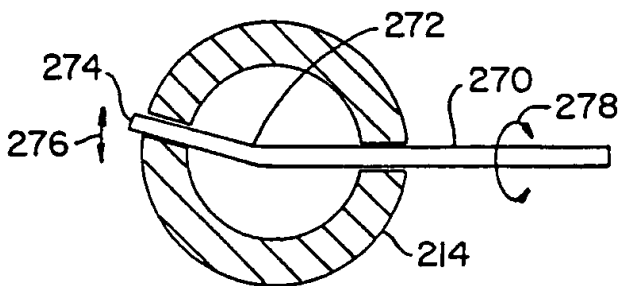
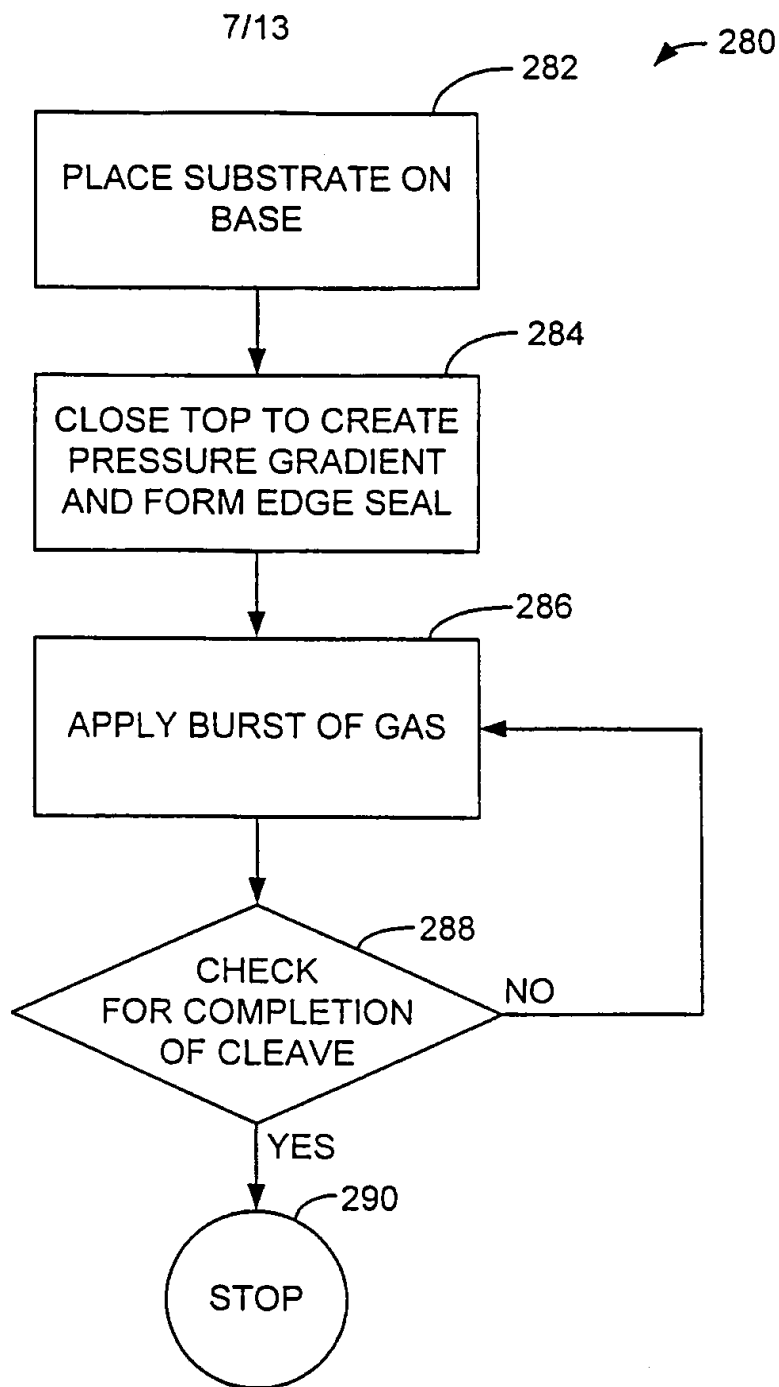
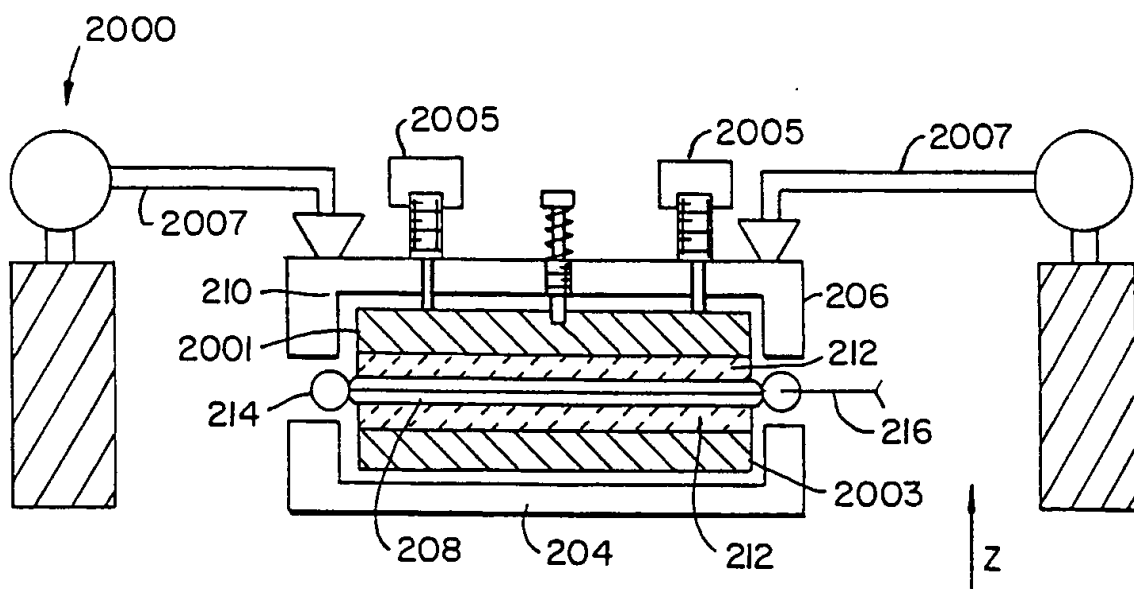


FIG. 2D.

**FIG. 2E.**

*FIG. 2F.*

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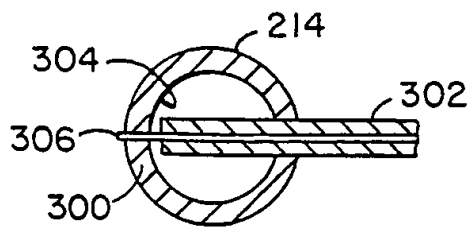


FIG. 3A.

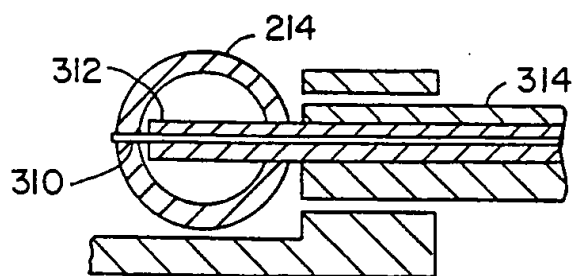


FIG. 3B.

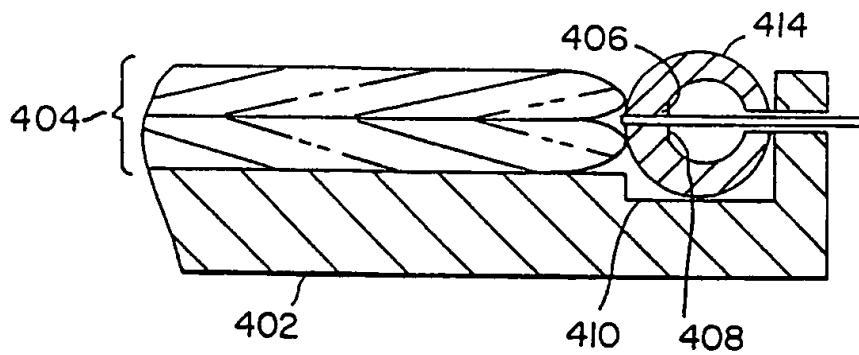


FIG. 4.

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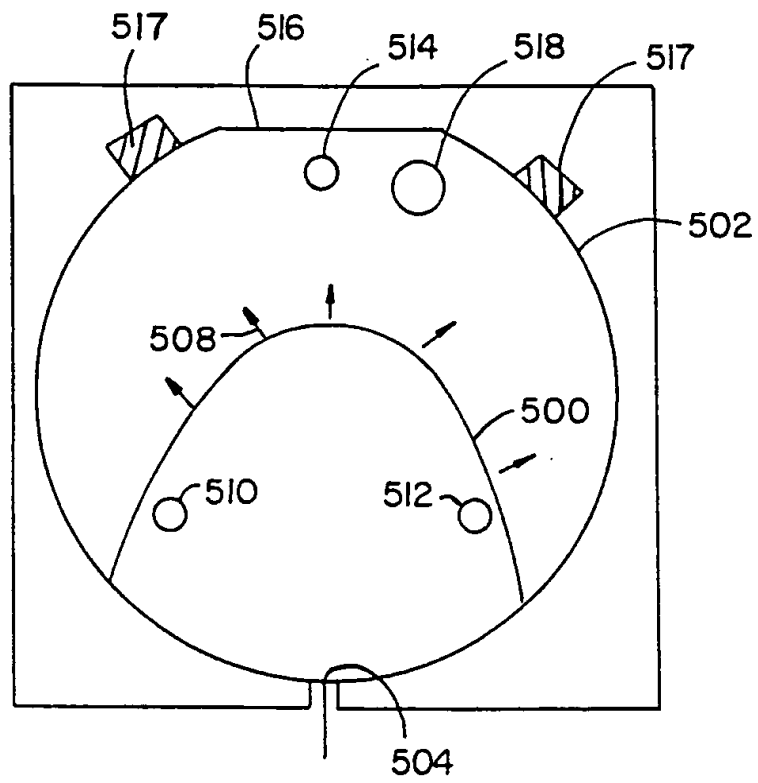


FIG. 5.

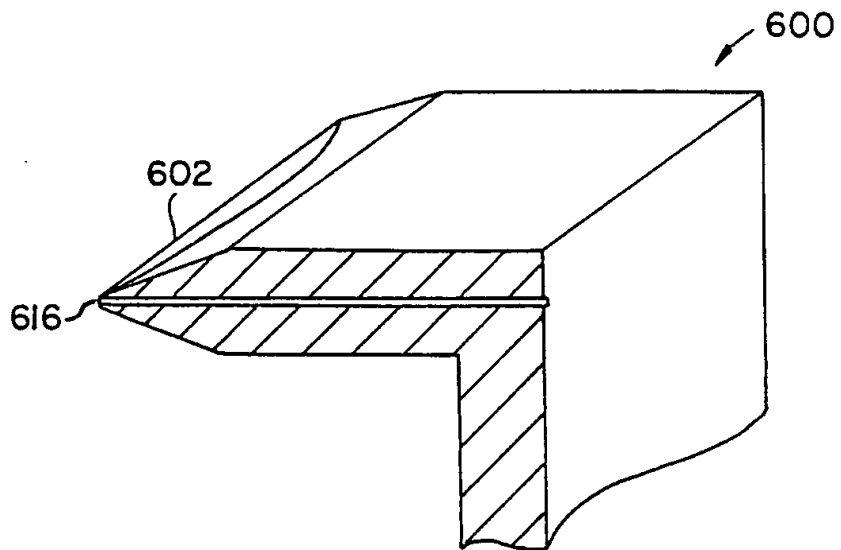
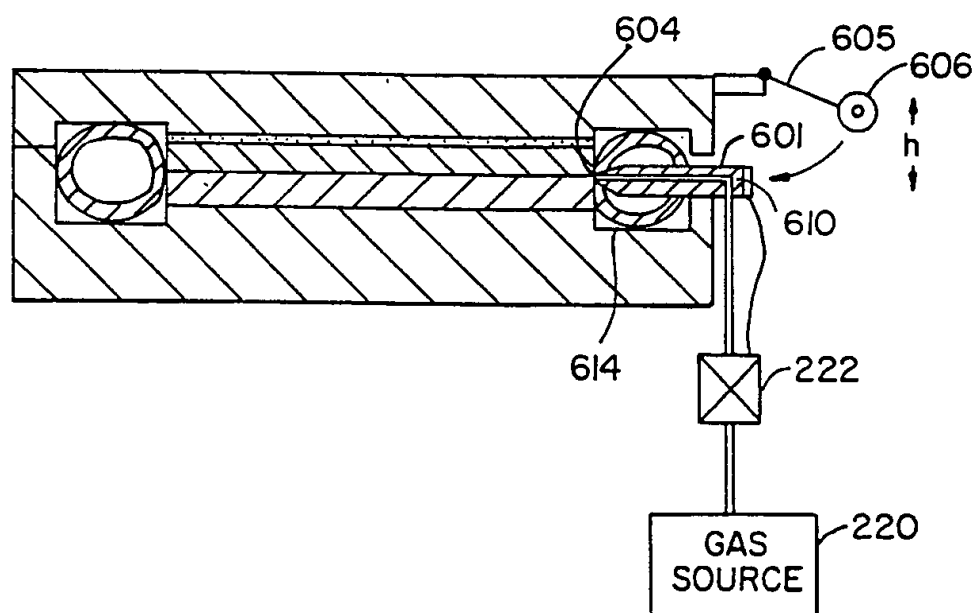
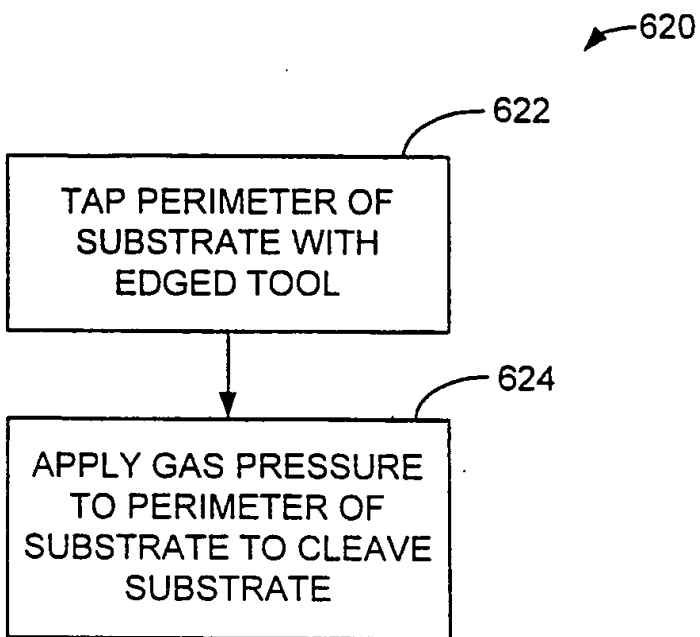


FIG. 6A.

*FIG. 6B.*

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**FIG. 6C.**

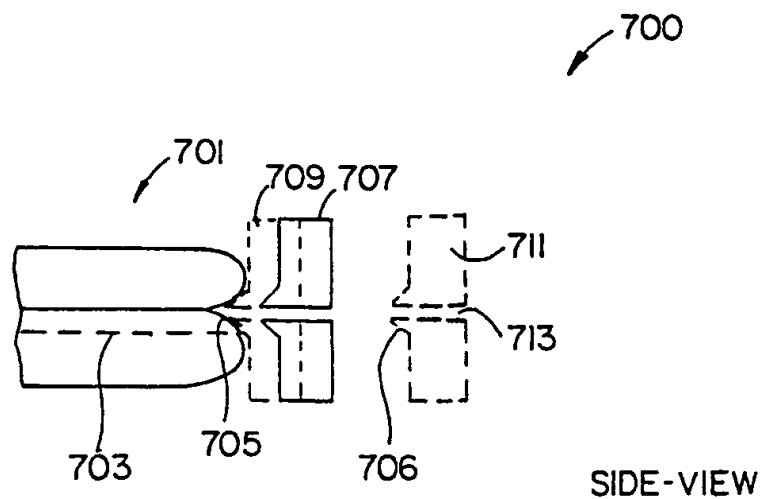
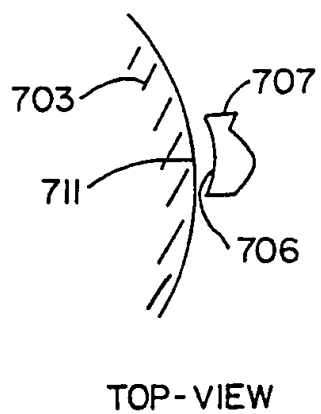


FIG. 7.



INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/US00/21006
A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B32B 35/00

US CL :Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 834,363 (DRESIA) 14 February 1952, page 2, lines 64-104.	1, 2, 8
X	US 1,275,192 A (ALEXIS) 13 August 1918, page 1, lines 59-70.	46, 47, 52
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Y		48-49
X	US 1,412,743 A (HERFJORD) 11 April 1922, page 1, lines 30-46.	46-47, 51, 52
---		-----
Y		48, 49
Y	US 2,518,273 A (BERGSTROM) 08 August 1950, col. 1, lines 27-35.	48
P, A	US 6,077,383 A (LAPORTE) 20 June 2000.	1-52

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

23 OCTOBER 2000

Date of mailing of the international search report

17 NOV 2000

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/21006

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	US 5,994,207 A (HENLEY et al.) 30 November 1999.	1-52
A	US 5,783,022 A (CHA et al.) 21 July 1998.	1-52
A	US 3,085,454 A (FEDERIGHI) 16 April 1963.	46-52
A	US 2,839,221 A (DEMARET) 17 June 1958.	46-52

5 metal. The top shell has a hard, rigid cap 210 and also a compliant pad 212. The cap is fabricated from tooling plate, while the compliant pad is, for example, a latex sheet approximately 1/8 inch thick with 30 durometer, but could be made of another compliant material, such as silicone, urethane, neoprene, or other rubber, or other compliant material. The compliant pad supports the upper surface of the composite
10 substrate during the cleave process while allowing the composite substrate to expand slightly to separate the composite substrate and transfer a thin film from the donor substrate to the handle substrate.

An O-ring 214 forms a seal around the perimeter edges of the composite substrate. The O-ring is hollow and operates at ambient (atmospheric)
15 pressure to provide a compliance of 30 durometer, but could be sealed and pressurized to control the compliance and sealing force, or could be solid. A gas port 216, in this case formed by a needle (e.g., tube) extending through the O-ring, provides a source of gas (e.g., static source, pulse) to a perimeter plenum formed by the sealed edge groove of the composite substrate. The O-ring 214 does not have to
20 seal the entire perimeter of the composite substrate, such as if the composite substrate has an alignment flat 218, as will be discussed below.

Gas is provided from a gas source 220, such as a dry nitrogen source, but could be other types of gases, such as air, argon, or helium. The gas flow is controlled by a solenoid valve 222, or similar valve, which controls the gas supplied
25 to the gas port 216. In a preferred embodiment, the gas source provides gas at a nominal pressure of about 300 psi., and the valve is controlled by a control line 224 to open for 22 msec. to provide a pulse of gas to the gas port 216. The dynamics of the gas are generally sufficient to initiate and propagate cleaving of the composite substrate. Gas may be lost through leakage between the O-ring and the substrate,
30 especially where the O-ring does not form a seal with the substrate, but such incidental loss appears to not be critical in cleaving the substrate. Multiple pulses of gas may be applied to facilitate cleaving, if necessary. Alternatively, the fluid may be replaced by a liquid or a combination of liquid and gas.

INTERNATIONAL SEARCH REPORT

Intern: Application No

PCT/TK 02/01253

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B28D5/00 H01L21/00 B32B35/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B28D H01L B32B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01 10644 A (SILICON GENESIS CORP) 15 February 2001 (2001-02-15) the whole document * en particulier: * page 5, line 20 -page 6, line 21 page 8, line 30 -page 9, line 21 page 10, line 5 - line 30 page 11, line 23 - line 24 page 16, line 29 -page 18, line 29 figures 5-7	1-5, 7-9, 11-14, 21-26
A	---	6, 10, 15, 17, 18
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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- *A* document defining the general state of the art which is not considered to be of particular relevance
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- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search

24 July 2002

Date of mailing of the international search report

31/07/2002

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INTERNATIONAL SEARCH REPORT

Internat Application No

PCT/FR 02/01253

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 867 917 A (CANON KK) 30 September 1998 (1998-09-30) the whole document * en particulier: * column 4, line 48 - column 5, line 57 column 17, line 8 - line 42 figure 9	1-4, 6, 8, 9, 11-13, 16, 19-24, 28, 29
A		17, 27
X	EP 0 977 242 A (CANON KK) 2 February 2000 (2000-02-02) paragraph '0272! - paragraph '0277! figures 15-17	1-4, 6, 8, 11-13, 21-24
X	US 6 050 255 A (SIEVERT DICK J) 18 April 2000 (2000-04-18) column 3, line 52 - line 57 column 6, line 62 - column 7, line 56 figures 1, 2A, 2B, 11, 12	1-5, 7, 8, 10-13, 16, 19, 20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/FR 02/01253

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WO 0110644	A	15-02-2001	US 6221740 B1	24-04-2001
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			US 6178704 B1	30-01-2001

RAPPORT DE RECHERCHE INTERNATIONALE

Dema Internationale No
PCT/FR 02/01253

A. CLASSEMENT DE L'OBJET DE LA DEMANDE

CIB 7 B28D5/00 H01L21/00 B32B35/00

Selon la classification internationale des brevets (CIB) ou à la fois selon la classification nationale et la CIB

B. DOMAINES SUR LESQUELS LA RECHERCHE A PORTE

Documentation minimale consultée (système de classification suivi des symboles de classement)

CIB 7 B28D H01L B32B

Documentation consultée autre que la documentation minimale dans la mesure où ces documents relèvent des domaines sur lesquels a porté la recherche

Base de données électronique consultée au cours de la recherche internationale (nom de la base de données, et si réalisable, termes de recherche utilisés)

C. DOCUMENTS CONSIDERES COMME PERTINENTS

Catégorie	Identification des documents cités, avec, le cas échéant, l'indication des passages pertinents	no. des revendications visées
X	WO 01 10644 A (SILICON GENESIS CORP) 15 février 2001 (2001-02-15) le document en entier * en particulier: * page 5, ligne 20 -page 6, ligne 21 page 8, ligne 30 -page 9, ligne 21 page 10, ligne 5 - ligne 30 page 11, ligne 23 - ligne 24 page 16, ligne 29 -page 18, ligne 29 figures 5-7	1-5, 7-9, 11-14, 21-26
A	-/-	6, 10, 15, 17, 18

☒ Voir la suite du cadre C pour la fin de la liste des documents

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Date à laquelle la recherche internationale a été effectivement achevée

24 juillet 2002

Date d'expédition du présent rapport de recherche internationale

31/07/2002

Nom et adresse postale de l'administration chargée de la recherche internationale

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RAPPORT DE RECHERCHE INTERNATIONALE

Demande internationale No
PCT/FR 02/01253

C.(suite) DOCUMENTS CONSIDERES COMME PERTINENTS

Catégorie	Identification des documents cités, avec, le cas échéant, l'indication des passages pertinents	no. des revendications visées
X	EP 0 867 917 A (CANON KK) 30 septembre 1998 (1998-09-30) le document en entier * en particulier: * colonne 4, ligne 48 - colonne 5, ligne 57 colonne 17, ligne 8 - ligne 42 figure 9	1-4, 6, 8, 9, 11-13, 16, 19-24, 28, 29
A		17, 27
X	EP 0 977 242 A (CANON KK) 2 février 2000 (2000-02-02) alinéa '0272! - alinéa '0277! figures 15-17	1-4, 6, 8, 11-13, 21-24
X	US 6 050 255 A (SIEVERT DICK J) 18 avril 2000 (2000-04-18) colonne 3, ligne 52 - ligne 57 colonne 6, ligne 62 - colonne 7, ligne 56 figures 1, 2A, 2B, 11, 12	1-5, 7, 8, 10-13, 16, 19, 20

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Renseignements relatifs : Membres de familles de brevets

Demande internationale No
PCT/FR 02/01253

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